इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 15678 (2006): Intelligent pigging of pressurized natural gas pipelines - Code of practice [PCD 3: Petroleum, Lubricants and their Related Products]

“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartṛhari—Nītiśatakam
“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE

BRUTUM FULMEN
IGNORANTIA JURIS NON EXCUSAT
PROTECTED BY COPYRIGHT

भारतीय मानक

दाब आरोपित प्राकृतिक गैस पाइपलाइन की इंटैलिज़ेंट पिगिंग — रीति संहिता

Indian Standard

INTELLIGENT PIGGING OF PRESSURIZED NATURAL GAS PIPELINES — CODE OF PRACTICE

ICS 75.200

© BIS 2006

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2006 **Price Group 9**

Petroleum, Lubricants and Their Related Products Sectional Committee, PCD 3

FOREWORD

This Code was adopted by the Bureau of Indian Standards, after the draft finalized by the Petroleum, Lubricants and Their Related Products Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

Underground cross country pipelines are a well-established convenient and cost effective means of transporting pressurized natural gas through pipelines over long distances of several hundred kilometres. It is essential to check, monitor and ensure the integrity of such a large magnitude of buried steel structure over the years. The random pipeline failures are a potential threat to the environmental pollution and safety of the public at large besides causing interruptions in the supply of essential commodities.

The integrity of buried cross-country pipelines is likely to be adversely affected despite appropriate design standards, manufacturing and construction codes. The main influencing factors are changes in soil resistivity, external interference, periodic inadequacy of corrosion protection system, pipeline age, man-made or natural ground movements and third party activities over the right of way.

For technical integrity assurance purposes the pressurized pipeline system can be treated like any other pressure vessel and theoretically conventional hydro test can be applied for integrity check. However, hydro test is only a fail/no fail test and provides no information about the existence including the density of sub-critical defects close to failure. Such defects may possibly be adversely influenced by the test itself. Further hydro test presents serious logistics problems related to disposing off the contaminated water, restricting public access in the testing zone and discontinuity in the product delivery during hydro test. Moreover, due to the inherent handicap of physical access to total pipeline structure, visual inspection and conventional non-destructive examination are not feasible like other pressure vessels.

In recognition of the above factors, through intensive research and developments, suitable inline inspection systems for cross country pipelines have been developed and commercialized in the last three decades. The most commonly used system for inline inspection is based on magnetic flux leakage (MFL) technology and is frequently used by pipeline owning companies to check the health of their pipeline systems. The technology, including the hardware and software used for the purpose have matured over the years and reasonably reliable results and very useful information is obtained through commercially available inline inspection tools. The general safety concentrations are covered in this Code, however, hazard related to stuck up due to design and installation of pipe, valves, tee, etc, condensate removing from the pipeline and pipeline health are not covered. This Code provides a uniform authentic reference to the pipeline operators which shall help them in taking decisions about selection of appropriate MFL tool besides keeping them fully aware as to what best can be expected out of intelligent pigging inspection. A regular update of this standard incorporating the recent developments in the technology shall make the document live and relevant for pipeline operating companies.

The pipeline design features and operating parameters have been suitably addressed in this Code. While selecting a specific intelligent pig tool for a particular pipeline segment, its suitability should be confirmed. Further, while evaluating the residual life of the pipeline, post-inspection, it is recommended to apply appropriate standards such as ASME B 31G 'Manual for determining the remaining strength of corroded pipelines' or Fitness for Purpose analysis can be carried out through fracture mechanics assessment techniques taking into consideration the applied stresses, defect size and location, and line pipe material toughness properties.

Considerable assistances have been derived from the following standards:

RP0102 – 2002	Standard recommended practice inline inspection of pipelines (NACE standard)
OISD – STD 141	Design and construction requirements for cross country hydrocarbon pipelines
OISD – STD 138	Inspection of cross country pipelines — Onshore
ASME B 31 . 8 : 2003	Gas transmission and distribution piping systems

(*Continued on third cover*)

AMENDMENT NO. 1 OCTOBER 2006
TO
IS 15678 : 2006 INTELLIGENT PIGGING OF PRESSURIZED NATURAL GAS PIPELINES — CODE OF PRACTICE

(*Second cover, Foreword, para* 5, *line* 6) — Substitute 'Considerations' *for* 'Concentrations'.

(*Third cover, Foreword, para* 1) — Insert the following new para after para 1:

'**1.1** In line with the practices followed in the industry in this field, units are given in FPS system also. For conversion of FPS units to corresponding SI units, the following conversion factors are applicable:

1"[inch] = 25 mm, for nominal sizes; otherwise 1"[inch] = 25.4 mm;

Each system shall be used independently of the other, without combining values in any way.'

(*Page* 3, *clause* 4, *line* 3) — Substitute 'an' *for* 'a'.

(*Page* 9, *clause* **7.2.1.1**, *line* 1 *and wherever it appears*) — Substitute 'shall' *for* 'must'.

(*Page* 13, *Table* 1, *Note* 4) — Substitute '1" = 25.4 mm' *for* '1" = 0254 mm'.

(PCD 3)

Reprography Unit, BIS, New Delhi, India

Indian Standard

INTELLIGENT PIGGING OF PRESSURIZED NATURAL GAS PIPELINES — CODE OF PRACTICE

1 SCOPE

The objective of inline inspection is to assess the health of the pipeline segment in quantifiable terms. The relevant data on pipeline condition can be generated by the application of appropriate tools and technology and the same is analyzed through industry accepted standards to arrive at the desired results.

2 APPLICABILITY

2.1 This Code has been specifically prepared for the inspection of underground carbon steel pipeline systems used for transportation of onshore pressurized natural gas by Intelligent Pigging. The standard provides recommendations to the pipeline operators.

2.2 This Code elaborates different techniques of intelligent pigging for onshore natural gas pipelines and its application. Though various techniques of intelligent pigging are available, this Code elaborates the MFL technique of pigging.

3 DEFINITIONS

The following terminologies are commonly used in inline inspection related activities.

3.1 Anomaly — Any kind of imperfection, defect, or critical defect that may be present in the wall of the pipe.

3.2 Characterize — To quantify the type, size, shape, orientation, and location of an anomaly, defect, or critical defect.

3.3 Cleaning Pig — A utility pig that uses cups, scrapers, or brushes to remove dirt, rust, mill scale, or other foreign matter from the pipeline. Cleaning pigs are run to increase the operating efficiency of a pipeline or to facilitate inspection of the pipeline.

3.4 Critical Defect — As used in this text, a subset of defect, for which an analysis, such as ASME B 31G, would indicate that the pipe is approaching failure at pressures equal to maximum operating pressure or the maximum allowable operating pressure for the pipe.

3.5 Corrosion

3.5.1 *General External* — Metal loss due to electrochemical, galvanic, microbiological, or other attack of the pipe due to environmental conditions surrounding the pipe.

3.5.2 *General Internal* — Metal loss due to chemical or other attack of the steel from gases inside of the pipe. Electrochemical attack can also occur in local cells, but this condition is less frequent.

3.6 Pit — Local concentrated-cell corrosion on the external or internal surfaces that results from the generation of a potential (voltage) difference set up by variations in oxygen concentrations within and outside the pit. The oxygen-starved pit acts as the anode and the pipe surface acts as the cathode.

3.7 Stress Corrosion Cracking — A progressive inter-granular and/or trans-granular cracking that results from a combination of applied tensile stress, cathodic protection currents, and a suitable corrosive environment.

3.8 Cracks

3.8.1 *Fatigue* — Progressive cracking in the base material, weld or weld zone that is caused by pressure cycling or oscillatory stresses associated with the operation of the system.

3.8.2 *Girth Weld* — Cracks in the weld or weld zone of the butt welds that connect sections of pipe.

3.8.3 *Seam Weld* — Cracks in the weld or weld zone of the longitudinal seam weld of the pipe.

3.9 Data Analysis — The process through which indications are evaluated to classify and characterize them as non-relevant conditions, pipeline components, anomalies, imperfections, defects, or critical defects.

3.9.1 *Defect* — As used in the text, an anomaly for which an analysis, such as ASME B31G, would indicate that the pipe is approaching failure as the nominal hoop stress approaches the specified minimum yield stress of the pipe material.

3.9.2 *Detect* — To sense or obtain a measurable indication from an anomaly in a pipeline.

3.9.3 *Dent* — A local depression in the pipe surface caused by mechanical damage that produces a gross disturbance in the curvature of the pipe without reducing the pipe wall thickness. The depth of a dent is measured as a gap between the lowest point of the dent and a prolongation of the original contour of the pipe.

3.10 **Flux** — The (scalar) number of flux lines crossing a unit area at right angles to the unit area.

3.11 **Flux Leakage** — The flow of flux out of a magnetic material, such as the wall of a pipe, into a medium with lower permeability, such as gas or air.

3.12 **Flux Lines** — A representation of the strength and direction of a magnetic field. Flux lines are drawn parallel to the direction of magnetic force. The spacing of these lines represents the magnetic field strength. Flux lines always form non-intersecting closed loops starting at the North Pole and ending at the South Pole of a magnet.

3.13 **Gauging Pig** — A utility pig that is permanently deformable by obstructions in the pipeline and thus, upon retrieval from the line, provides evidence of the worst-case obstruction in a given pipeline segment.

3.14 **Geometry Pig** — A configuration pig designed to record conditions, such as dents, wrinkles, ovality, bend radius and angle, and occasionally indications of significant internal corrosion, by making measurements of the inside surface of the pipe.

3.15 **Gouges** — Mechanical or forceful removal of metal from a local area on the surface of the pipe that may work harden the pipe and make it more susceptible to cracking.

3.16 **Hall-Effect Sensor (Hall Elements)** — A type of sensor that directly measures magnetic field. Hall-effect sensors require power to operate.

3.17 **Hard Spots** — Localized changes in hardness of the steel in the pipe resulting from non-uniform quenching procedures during the manufacture or changes in chemistry of the steel. Hard spots, when stressed, are subject to failure from mechanisms, such as hydrogen-stress cracking.

3.18 **Induction Coil Sensor** — A type of sensor that measures the time rate of change in flux density. Induction coil sensors do not require power to operate.

3.19 **Inspection** — (1) The process of examining a pipe using a non-destructive testing technique to look for anomalies or to evaluate the nature or severity of an indication. (2) The process of running a configuration tool or an inline inspection tool through a pipe to detect anomalies.

3.19.1 *Inline Inspection (ILI)* — The inspection of a pipeline from the interior of the pipe using an inline inspection tool.

3.19.2 *Inline Inspection Tool* — The device or vehicle, also known as an intelligent or smart pig, that uses a non-destructive testing technique to inspect the wall of a pipe. An inline inspection tool is one type of instrumented tool.

3.20 **Launcher** — A pipeline facility used for inserting a pig into a pressurized pipeline.

3.21 **Lamination** — A type of imperfection or discontinuity in the pipe wall with a layered separation usually aligned parallel to the working direction of the metal.

3.22 **Magnetic Field** — A vector quantity representing the force of attraction that a magnet exerts on steel pieces and on other magnet poles.

3.23 **Magnetic Field Strength** — The magnitude of the magnetic field produced by a magnet.

3.24 **Metal Loss** — Several types of anomalies in pipe in which metal has been removed from the pipe surface, usually due to corrosion or gouging.

3.25 **Permanent Magnet** — A type of magnet that requires no electrical current to generate a magnetic field.

3.26 **Permeability** — (1) The ability of magnetic flux to diffuse through (or permeate) a magnetic material. (2) The ratio of magnetic flux density to magnetic field strength.

3.27 **Pig** — A generic term signifying any independent, self-contained device, tool or vehicle that moves through the interior of the pipeline for purposes of inspecting, dimensioning, or cleaning. All pigs in this report are either utility pigs or instrumented tools.

3.28 **Pipe** — As used in the text, the steel pipe exclusive of protective coatings or attachments that is used to transport natural gas.

3.29 **Pipeline** — That portion of the pipeline system between the compressor stations including the pipe, protective coatings, cathodic protection system, field connection, valves and other appurtenances attached or connected to the pipe.

3.30 **Saturation** — The degree of magnetization where a further increase in magnetic field strength produces a decrease in permeability of a material.

4 PRINCIPLE OF MAGNETIC FLUX LEAKAGE

When a magnet is placed next to a pipe wall, most of the magnetic flux lines pass through the pipe wall. That is pipe wall is a preferred path for the flux. Flux leakage at a metal loss region is caused by a local decrease in the thickness of the pipe wall. At a metal loss region, a flux carried by the thin section is less than that carried in the full cross section of the pipe wall. Flux leaks from both the surfaces of the pipe wall. A sensor positioned on the inside of the pipeline is typically used to record this leakage flux. In this manner a MFL tool detects a anomaly that causes flux to leak. The measured leakage field depends upon the radial depth, axial length, circumferential width and shape of the anomaly as well as magnetic properties of the material. The typical phenomena of magnetic flux leakage have been schematically shown in Fig. 1.

5 COMMERCIALLY AVAILABLE PIPELINE INSPECTION TOOLS ON MFL PRINCIPLE

The pipeline inspection tools based upon their capabilities, which work on the principle of magnetic flux leakage principle, can be categorized as under.

5.1 Standard/Conventional MFL Tool

These are first generation inspection tools, which were developed and initially used during early stages of commercialization of MFL technology for pipeline inspection. However, they have a limited utility even today for cases where the pipeline operator does not require a detailed analysis and characterization/sizing of the defects. These tools have much less numbers of sensors and can reliably detect the defect but not size them for the purposes of defect analysis.

5.2 High Resolution MFL Tool

A high resolution MFL tool comprises of a large number of sensors and employs digital recording. The sensor sizing and the axial sampling interval determine the tool resolution and the ability to accurately characterize the defect. A typical high resolution tool has an axial sampling rate (Data recording of signals from individual sensors) of 3 mm and a sensor size is so designed that the smallest defect is not missed during data collection. A typical high resolution MFL tool is shown in Fig. 2.

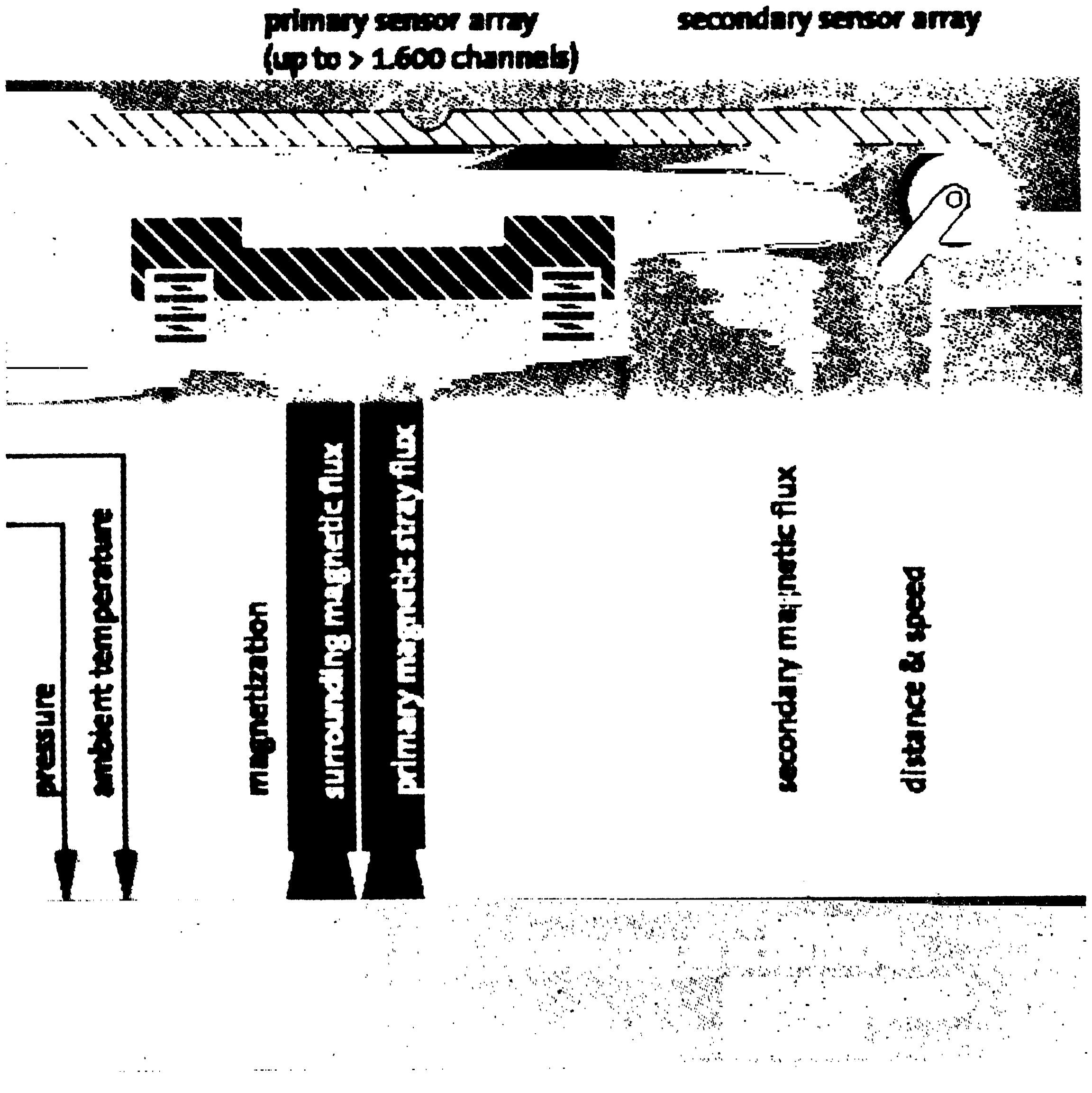


FIG. 1 BASIC PRINCIPLE OF MAGNETIC FLUX LEAKAGE

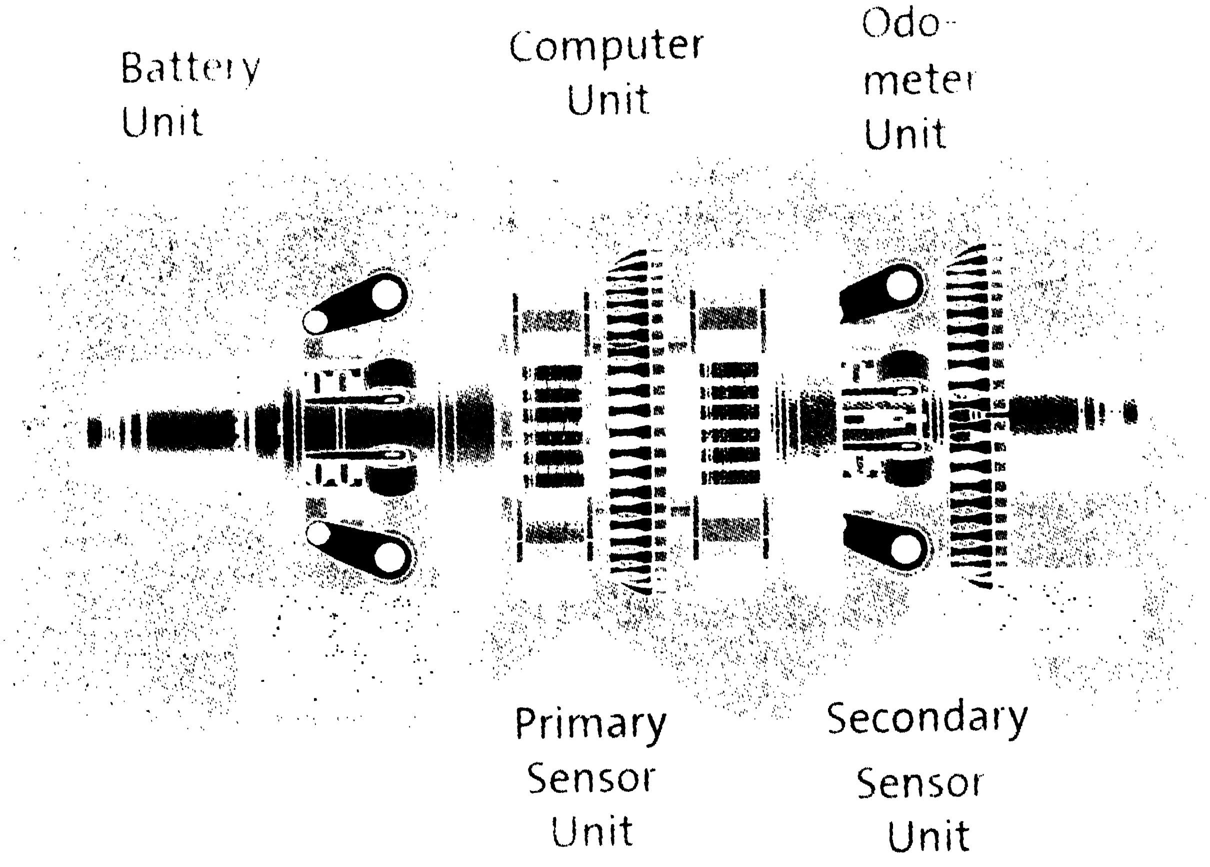


FIG. 2 TYPICAL HIGH RESOLUTION MFL TOOL

5.3 Transverse Field Inspection (TFI)

In case of a standard and high resolution MFL tool, the magnets are placed on the tool body in such a manner that magnetic field is introduced into the pipe wall in the longitudinal direction while in case of a TFI tool the magnets are so arranged that the magnetic field is introduced into the pipe wall in a transverse direction, thus enhancing the capability of MFL tool to detect longitudinal crack like defects. A typical TFI tool is shown in Fig. 3.

6 COMPONENTS OF A TYPICAL MFL BASED TOOL

6.1 MFL tools deployed for pipeline inspections are self-contained modular units comprising of modules having magnets, sensors, data conditioning and recording systems, and power systems. These modules are connected with each other by flexible universal joints. The systems used in most MFL tools include the following.

6.1.1 Drive system, which is used to propel the tool through the pipeline. Differential pressure acting on the drive system pulls the tool through the pipeline.

6.1.2 Power system, which provides battery power for the sensor system, data conditioning system, and recording system.

6.1.3 Magnetization system for magnetizing the pipe wall.

6.1.4 Sensor system, used to measure the flux-leakage signal.

6.1.5 Data conditioning and recording system, which amplifies, filters, and stores the measured signals.

6.2 Drive System

The force exerted by gas medium pushing on a cup or set of cups at the front of the tool pulls the tool through the line. Differential pressure acting between the front and back of the drive cups provides a force along the pipe axis. This force propels the drive cups, which in turn pull the rest of the tool.

The driving force on a tool must overcome the friction between the tool and the pipe and the magnetic drag that the tool exerts. The pressure differential required to move most tools is small.

The drive cups are typically at the front of the tool. Additional cups can be used to center each tool segment

FIG. 3 TYPICAL TRANSVERSE FIELD INSPECTION TOOL

in the pipeline. To prevent gas pressure from pushing a trailing segment of the tool into the leading segments, the gas is vented through holes in trailing cups.

MFL tools often have two or more drive cups. Multiple drive cups help the tool traverse pipeline connections. At the connections and at valves, the differential pressure across a cup can drop if gas bypasses around the cup. A second set of drive cups helps overcome this problem if the cups are spaced far enough apart so that one cup is always away from the connection or valve.

6.3 Magnetization Systems

An MFL tool contains a system that magnetizes a length of the pipe wall. Typically, sets of magnets are used to provide coverage around the circumference of a pipe. Generally permanent magnets are used. Permanent magnets have a constant magnetic strength and they require no power to operate.

The body of an MFL tool contains the permanent magnets. A brief description of other components of magnet system and their functioning is as under.

6.3.1 *Magnet Strength*

The data recording capabilities of an MFL tool strongly depend on the applied magnetic field strength. In general, the required design strength of a magnet system depends on the wall thickness and properties of the material of construction of the pipe to be inspected.

6.3.2 *Magnet Orientation*

The magnetizing assemblies in all currently available tools are oriented with their backing bars along the pipe axis. So, the flux lines that are produced are parallel to the axis of the pipe. The open area between the poles is a logical space to place sensors to measure the flux leakage from metal-loss regions. By using magnet and sensor assemblies around the pipe circumference, enables the full (100 percent) monitoring of the flux leakage at the inside pipe surface.

6.3.3 *Magnet Mounting Systems*

The tools are provided with brushes for coupling of the magnetic field into the pipe. Brushes help absorb the shock that can result at internal penetrations such as weld roots, restrictions, and dents in the pipeline. For tools with solid magnetic shoes, the dynamic performance is not as smooth, but the magnetic coupling is better. Spring mounting systems are used to attach the magnets to the body of the tool. These systems help center the tool in the pipe, and they absorb and damp the vibrations.

6.3.4 *Brushes, Backing Bars and Other Magnet Components*

The flux leakage field is a function of the strength and uniformity of the flux density in the pipe and in the surrounding gas. The flux density depends on the strength and orientation of the magnets and on the entire system used to channel the magnetic flux into the pipe. So, the selection of the other magnetizing assembly materials is important.

To reduce the likelihood of flux leakage around the backing bar, materials with high magnetic permeability, such as pure iron and silicon-based transformer steels, are typically used. To further reduce stray flux leakage, the backing bars thickness usually exceed the maximum wall thickness of pipe. In this way, the magnetic field in the pipe is not limited by the field that can be carried by the backing bars.

6.3.5 *Sensor Systems*

Sensors are the heart of any MFL inspection tool and are located between the magnet pole pieces to measure the flux leakage field. The purpose of sensor systems is to convert the flux leakage field into a signal that can be stored and analyzed. The sensor system consists of the sensors themselves, the mounting system used to support the sensors, wear plates between the sensors and the pipe, and cabling between the sensors and other electronic components.

6.3.6 *Sensor Types*

Two types of sensors commonly used in MFL tools are 'induction coils' and 'Hall elements' (field sensor). Coils measure the rate of change of a magnetic field, which in this case is the leakage flux while Hall elements measure the actual magnetic field strength. Induction coils are the most commonly used type of sensor on MFL inspection tools because they do not require a power source. Instead, a voltage is generated in a passive coil of wire or printed circuit as it passes through a changing magnetic field. A recording device measures this voltage, which is proportional to the change in flux density. Since a coil responds to rate of change in flux density, the output of a coil is a function of the speed at which it is moving.

Hall elements are not as commonly used on MFL tools as induction coils because they require power to operate. Since the battery power is limited and inspections are many hours long, sensors that require power to operate must output unique information to justify their use. In a Hall element, an electrical current is distorted by the presence of a magnetic field. A recording device measures the change, which is proportional to the strength of the magnetic field and the amount of current. Although electrical power is required to generate the current, Hall elements are not sensitive to speed, which makes them attractive for some applications. Several recently introduced MFL tools use Hall elements alone or in combination with coils.

6.3.7 *Sensor Size*

An important sensor parameter is its size. Sensor size and therefore number of sensors in a tool directly impacts the resolution of the measurement system. The axial length of a sensor and the sampling or data acquisition rate define the axial resolution of the measurement system. Sensors are usually less than one inch long. The circumferential width of a sensor defines the resolution around the pipe circumference. The width of the sensors in typical systems is generally less than half inch. The radial height of a sensor is usually less than one inch.

6.3.8 *Sensor Orientation*

A single sensor measures in only one direction, and so, it measures only one component of the flux leakage field. Most commercial MFL inspection systems measure the radial or axial component of the flux leakage field. The third component in the circumferential direction is usually ignored due to its low amplitude.

6.3.9 *Other Sensor Consideration*

Most MFL tools attempt to determine whether a metal loss region is on the inside or the outside surface of the pipe.

Additional sensors are required for this purpose. These are often referred to as inside diameter/outside diameter sensors. These are suitably mounted on the tool assembly.

6.4 Data Conditioning and Recording Systems

The amount of data generated during an inspection is large. As a result of high volume of data, many tool designers use data conditioning systems to compress the data and reduce storage requirements. For example, the amount of data stored can be reduced by recording only channels with changing signals. This type of data compression technique requires a threshold to be defined prior to the inspection.

Data are stored in an analog or digital fashion on either tape or solid-state memory boards.

Most of the recently developed high-resolution MFL tools use digital recording systems. Digital systems require on-board analog-to-digital converters, which add power, size, and complexity to the tool. Digital systems provide more safeguards on data integrity (error checking) and allow easier data compression. Digital systems also provide data in a format suitable for use in computerized analysis systems.

6.5 Power Systems

The data conditioning and data storage devices that are used in an MFL tool require a significant amount of power to operate. So, the battery power that is available limits the mileage that can be inspected at any time. Most tools use rechargeable battery systems; the capacity of these systems and the energy requirements for the operating systems define the maximum inspection length.

Several types of standard battery packs are available. Proprietary designs may use nickel cadmium cells and lead acid cells. These cells are usually connected in series to produce the desired voltage. Encapsulation of the battery units reduces shock and vibration effects. These types of battery packs have been used successfully for years and are considered extremely rugged and reliable.

6.6 Other Components and Systems

6.6.1 *Odometer Systems*

All the MFL tools have odometer systems. Signals from odometer wheels are used to estimate the location of indications from the start of the inspection or from recognizable features along the pipeline route. Recognizable features include pipeline connections, valves, wall thickness changes at road crossings, and girth welds.

The accuracy of the odometer system depends on the size of the odometer wheels. Slippage of the odometer wheels on the inside of the pipe also affects the accuracy. For this reason, markers (magnetic markers or locator coils) that produce and record signals that can be detected by the inline inspection tool are often placed at known places along the pipeline 'right of way (ROW)' to create reference points for later 'defect verification' purposes.

6.6.2 *Orientation Measuring Systems*

Most MFL tools contain pendulum-type orientation-measuring systems. These systems are used to determine the circumferential location of an indication.

6.6.3 *Pressure Containment Systems*

All MFL tools are provided with small pressure vessels in which electronic and battery components are mounted. These pressure vessels prevent damage to tool components from the line pressure, harmful gas components, and moisture.

7 FACTORS INFLUENCING THE TOOL PERFORMANCE

There are a number of factors that affect the anomaly detection and characterization capabilities and accuracy by MFL tools. These can be grouped into two main areas: Tool Design Parameters and Pipeline Design Features and Operating Parameters.

7.1 Tool Design Parameters

The following factors related to tool design are important for detection and characterization of anomalies in the pipe wall.

7.1.1 *Magnetization Level*

The detection is most strongly affected by the magnetic field strength while good characterization requires a magnetic field that is strong, uniform and consistent. The magnetic strength has the strongest impact on the applied magnetic field. The magnetization systems in MFL tool are usually designed to produce near magnetic saturation in the pipe wall so that a reduction in the pipe wall material will cause flux to leak. The strength of the magnetization system must be tailored to the wall thickness of the pipe proposed to be inspected. The typical magnetization curve for low, medium and high magnetization levels and corresponding flux leaks are shown in Fig. 4 and Fig. 5.

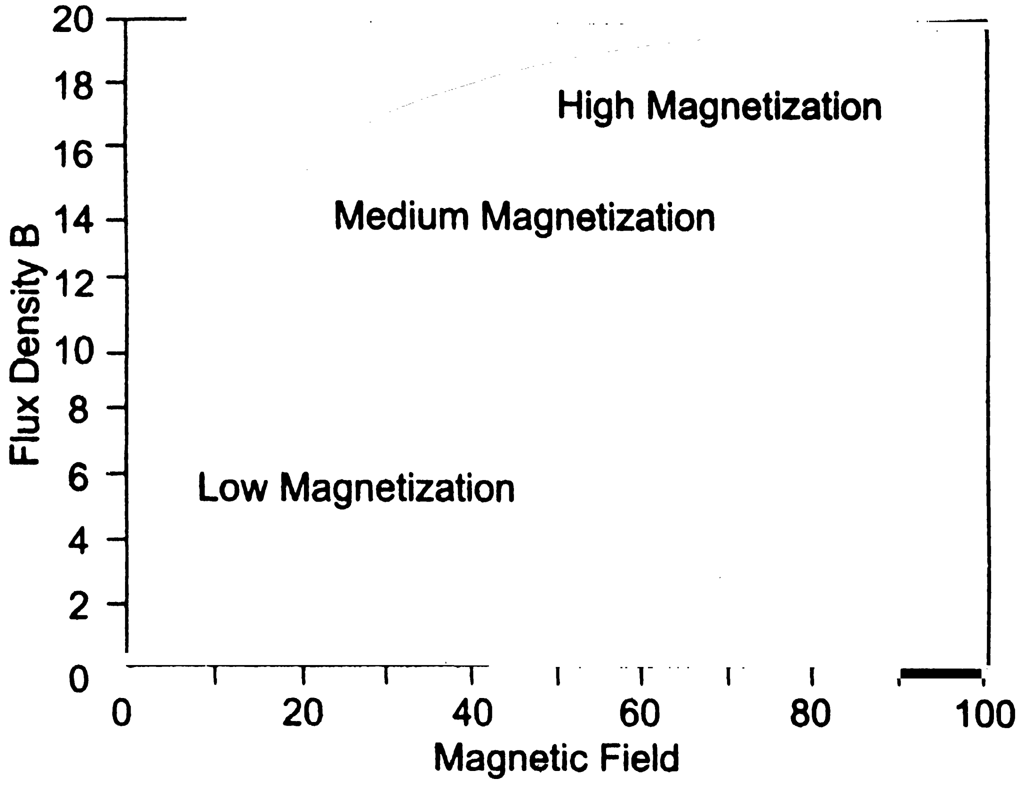


FIG. 4 TYPICAL MAGNETIZATION CURVE

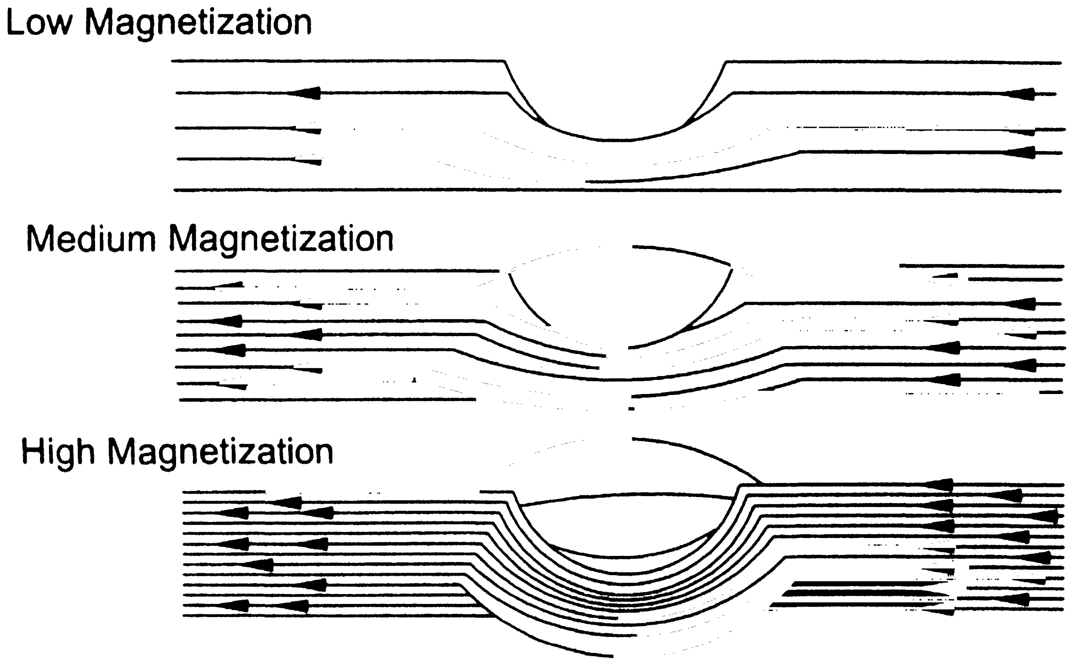


FIG. 5 FLUX LEAKAGE AT THREE MAGNETIZATION LEVELS

7.1.2 *Sensor System*

Sensor size directly impacts the resolution of the measurement system. All sensors have an axial length, circumferential width, and radial height, and they provide an average measurement of the flux passing through the volume of the sensor. The resolution of a system is defined by the circumferential width of the sensor. The use of narrow sensors improves system resolution by providing more signals for analysis from a given metal loss region.

When the sensor width is of the order of or greater than the width of a defect, flux leakage levels may not be properly measured. Damage processes that leave short defects, narrow pits or pinhole defects, require small sensors for accurate defect detection and sizing.

MFL pigs record flux leakage at specified intervals in both the axial and circumferential directions in the pipe. The data-recording interval in the circumferential direction is defined by the number of sensors and in the axial direction is defined by the sampling rate. The latest generation inspection pigs have an order of magnitude more sensors. A high-resolution MFL tool suitable for 24" diameter pipeline will typically have between 150 and 300 sensors, thus the circumferential data interval be between 0.25 and 0.5 inches (6.4 and 12.8 mm). The axial data recording intervals (sampling rate) is dictated by the data recording system, and is usually between 0.1 and 0.2 inches (2.5-5.0 mm).

7.2 Pipeline Design Features and Operating Parameters

The following features related to pipeline design and operating parameters have significant bearing on the successful performance of the MFL tool.

7.2.1 *Pipeline Design Features*

7.2.1.1 Launching and receiving facilities must be adequate for the type of tool. Launchers and receivers may be installed with new construction or during modification of existing facilities and may be permanent or temporary installations. Consideration should be given to the following:

a) *Workspace availability* — The work area should be reviewed to ensure sufficient space for manoeuvring tools and associated equipment (for example, cranes and lifting equipment) during loading and unloading of live inspection tool.

b) *Adequate barrel length* — Sufficient room must be maintained between the door and the isolation valve such that the proposed inspection tool can be accommodated in that length. For launchers, the oversize section length should be greater than or equal to the tool length; nominal pipe length can be kept to a minimum. In cases in which the oversize section is shorter than the tool length, significant consideration must be given to alternative loading methods such as pulling a tool in. For receivers, the nominal pipe section length must be greater than or equal to the tool length to ensure the entire tool will clear the isolation valve. The length of the oversize section must be sufficient to accommodate the tool stopping distance upon receipt. Actual length requirements may vary depending on the tool used.

7.2.1.2 Internal diameter changes (for example buckles, dents, bore restrictions, reduced port valves, and checks valves) can be present in the line for many different reasons and should be addressed before the internal inspection. Sometimes the tool is able to negotiate these types of restrictions, but each situation should be assessed on a case-by-case basis.

7.2.1.3 Probes intruding into the pipeline can restrict inspection tools. Neglecting to remove them can damage the facilities and the tools.

7.2.1.4 Wall thickness is an important parameter for which some tools need to be calibrated and thus should be considered by the vendor. ILI vendors should be alerted if line wall thickness is less than 6.4 mm (0.25 inch) or greater than 13 mm (0.50 inch). Smaller diameter lines with heavy wall pipe may severely limit the number and types of tools that can be successfully used.

7.2.1.5 *Short radius bends*

The majority of inspection tools are capable of negotiating a 3*D* bend radius or greater. Any bends that are tighter shall be addressed on a case-by-case basis depending on the tool to be used and the wall thickness of the bend. An increasing number of tools are capable of passing a 1.5 *D* bend radius.

7.2.1.6 *Back-to-back bends*

Bends installed in a back-to-back configuration, that is, without an intervening section of straight pipe between the bends, can present an impediment or sticking hazard for ILI tools.

7.2.1.7 *Valves*

Reduced port valves can result in tool damage and in extreme cases can result in the tools becoming lodged in the line. Close attention shall be given to the ability of the tools to negotiate through check valves. Check valves flappers shall be locked in the open position during pigging operations.

7.2.1.8 Field bends and river crossings shall be reviewed thoroughly, because older construction lines may contain tight radius bends, miters and step transitions. These locations are potentially more susceptible to geo-technical movement and may have pipeline deformations that need to be detected before inline inspection is attempted.

7.2.1.9 Internal coating can interfere with inspection. Conversely, certain tools can damage internal coatings. Thus, this factor shall be considered prior to inline inspection commencement of pigging operations.

7.2.1.10 Sales taps/feeds shall be reviewed. In most cases, the sales taps and feeds shall be isolated as the ILI tool passes. Factors affecting this decision include size and orientation of tap, amount of flow, amount of line debris, and type of tool.

7.2.1.11 *Unbarred and back-to-back tees*

Branch connections (30 percent of the pipe diameter or greater) should have scraper bars; however, larger unbarred branch connections may be tolerable depending on tool geometry and orientation. Hot taps, also identified as sharp edges can present a hazard to the tools. The dimensions between tees shall be reviewed keeping the specific ILI tool in mind, because back-to-back tees can create a situation in which the ILI tool gets lodged. This results when the geometry of the tees, combined with the cup spacing of the tool is such that the propelling product can follow a path around the tool without providing any driving force to the tool.

7.2.2 *Pipeline Operating Parameters*

7.2.2.1 *Temperature and pressure*

Most tools have specific temperature and pressure ranges for operation that shall be addressed in advance.

7.2.2.2 *Gas composition considerations*

The product if contains chemicals such as H_2S, modification to the standard tool design shall be considered to deal with the corrosive properties.

7.2.2.3 *Insufficient product flow*

When low flow gas lines are inspected using an MFL tool equipped with induction coils, the normal pipeline flow may need to be supplemented with additional product to achieve the minimum required inspection velocity.

7.2.2.4 *Tool velocity*

The tool velocity, which is practically the same as the gas velocity in the pipeline has significant effect on the magnetic flux leakage field. In general, leakage fields signals from shallow regions of defect are more affected than those from deep regions.

7.2.2.5 *Effect of stress*

The magnetic properties of a material change with the application of stress. The change in magnetic properties affects both the applied field strength and the uniformity of the flux density around a defect. Stress in a pipeline arises due to gas pressure and residual stresses from the fabrication process including bending/welding. In addition, metal loss regions, dents, and attachments act as stress risers that increase locally the effects of stress even further. Stress changes the overall (bulk) permeability of steel and it changes the local permeability around the defect. The effects of stress are greatest at low magnetization levels. At high levels, the inspection signals are nearly independent of stress. To reduce the effect of stress, the latest generation of MFL inspection tools uses extremely high magnetic intensities to detect and size metal loss defects.

7.2.2.6 *Effect of remnant magnetization*

The remnant magnetization changes the applied flux levels, it also affects the flux leakage field and the ability to detect and characterize metal loss. The results indicate that the flux leakage fields drop after each magnetization. These effects diminish with repeated magnetizations. For defects that are circumferentially wide and deep, there is a large initial drop in flux leakage. The axial length of the defect does not seem to have a significant effect on signal shape and size.

Hard spots in a pipe have a higher remnant magnetization than the surrounding pipe material. Therefore, hard spots can be located by measuring the remnant magnetization level using a sensor that trails behind the magnetizing assembly.

7.2.2.7 *Effect of noise and background signals*

An MFL inspection pig passing though a pipeline detects small changes in flux leakage in the absence of defects. These signals, referred to as noise, are a result of variations in magnetic properties and wall thickness in a pipe. So, they are repetitive from run to run. Noise signals are due to natural variation of magnetic properties, wall thickness changes, sensor liftoff variation, random noise. Seamless pipe produces noise levels that are especially severe.

8 DEFECT CHARACTERIZATION

Detection, Identification and sizing of the metal loss features with a confidence level and probability of detection are called Defect characterization. All the metal loss features need to be characterized with at least 80 percent confidence level and 90 percent probability of detection.

8.1 Detection

All metal loss features are required to be detected with kilometer chainage and circumferential orientation by the proposed MFL tools within the acceptable tolerance for defect location (*see* 9).

8.2 Identification

All metal loss features should be categorized according to their shape and size as under.

The geometrical representation of these metal loss features with respect to their width and length have been shown in Fig. 6.

8.3 Pinhole

If the length (L) and width (W) of the flaw is equal to or less than $A \times A$, it is categorized as Pinhole where $A = 10$ mm, if nominal pipe wall thickness is less than 10 mm and $A = t$, if pipe wall thickness (t) is ≥ 10 mm.

that is $0 < W < 1A$ and $0 < L < 1A$

8.4 Pitting

The metal loss flaw is defined as pitting, if its length (L) and width (W) conform to the following sizing:

$A \le W \le 6A$ and $A \le L \le 6A$

and not $W \ge 3A$ and $L \ge 3A$

8.5 General Corrosion

The metal loss corrosion is identified as general corrosion, if its length (L) and width (W) conform to the following sizing:

$W \ge 3A$; and $L \ge 3A$

8.6 Axial Grooving

The metal loss is identified as axial grooving, if its length (L) and width (W) conform to the following sizing:

$1A \le W \le 3A$ and $L/W \ge 2A$

8.7 Circumferential Grooving

The metal loss is identified as circumferential grooving, if its length (L) and width (W) conform to the following sizing:

$L/W = 0.5$ and $1A < L < 3A$

8.8 Slotting

The metal loss is identified as axial/circumferential slotting, if its length (L) and width (W) conform to the following sizing:

a) Axial slotting:
$0 < W < 1A$; and $L = 1A$

b) Circumferential slotting:
$W = 1A$; and $0 < L < 1A$

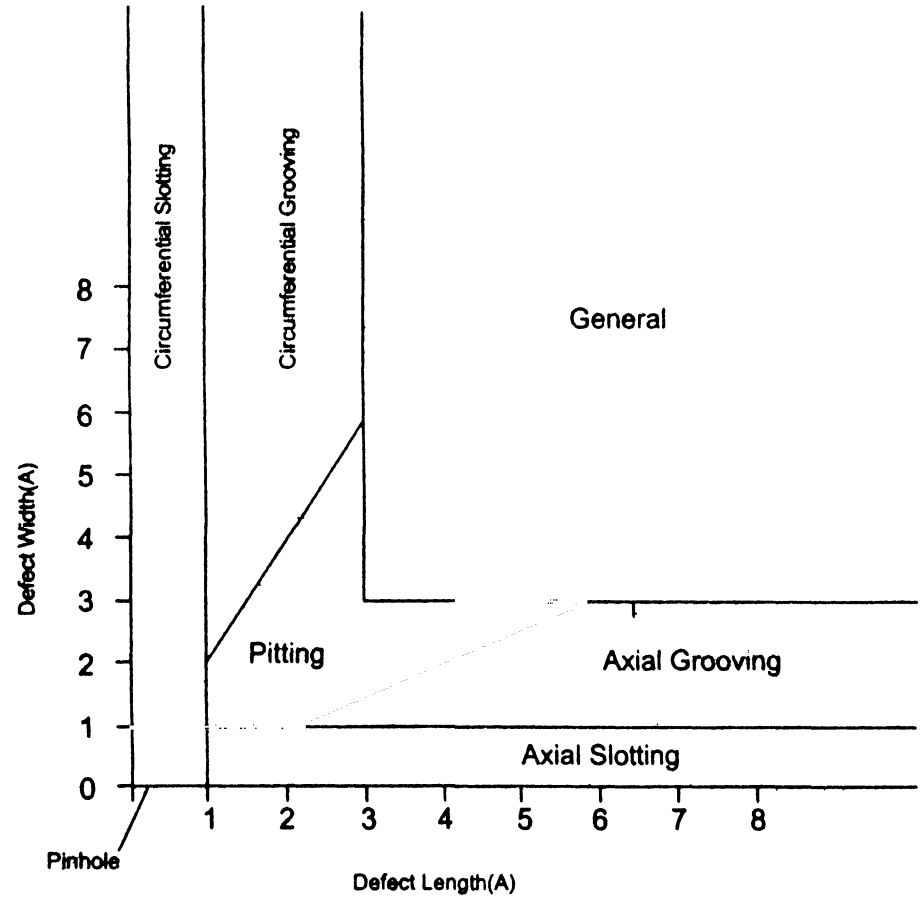


FIG. 6 GEOMETRICAL REPRESENTATION OF METAL LOSS FEATURE DEFINITIONS

8.9 Crack Type Features

In some cases the scope of work for the inspection will include the detection of cracking in addition to the detection of metal loss. Where this is the case the cracking may be classified into:

a) Girth weld cracking,
b) Longitudinal seam weld cracking,
c) Stress corrosion cracking, and
d) Hydrogen induced cracking (HIC).

9 METHODOLOGY OF METAL LOSS FEATURES SIZING FOR LENGTH (*L*), WIDTH (*W*), DEPTH (*D*) AND ORIENTATION

9.1 The start and endpoint of a metal loss feature is determined by the measurement threshold as indicated in Fig. 7. The length, '*L*', of an individual metal loss feature is given by the projected length on the longitudinal axis of the pipe. The width, '*W*', of an individual metal loss feature is given by its projected length on the circumference of the pipe.

9.2 The depth of the metal loss '*d*' is determined by the maximum wall loss in a metal loss feature and can be given as a depth from or percentage of the reference wall thickness.

9.3 Where no metal loss feature interaction rules are specified, two individual metal loss features interact and shall be clustered when the axial spacing between the metal loss feature edges is less than the smallest metal loss feature length and the circumferential spacing is less than the smallest metal loss feature width.

10 METAL LOSS DETECTION AND SIZING ACCURACY LEVELS

The magnetic flux leakage (MFL) technique is an indirect method of detecting and characterizing the pipeline anomalies. This depends on a number of tool design and pipeline operating/constructional features, which have been detailed out at 7. Like any other measurement, there will therefore be some tolerances in the anomaly sizing.

The characterization accuracy levels for various types of metal loss features for ERW pipes, seamless pipes and for the flaws located in the heat affected zone shall be different and the accepted accuracy levels at 90 percent Probability of Detection (POD) with 80 percent confidence level are given in Table 1.

11 DEFECT VERIFICATION

To verify the tool performance within the specified tolerance of the recorded/reported data as per **10**, it is

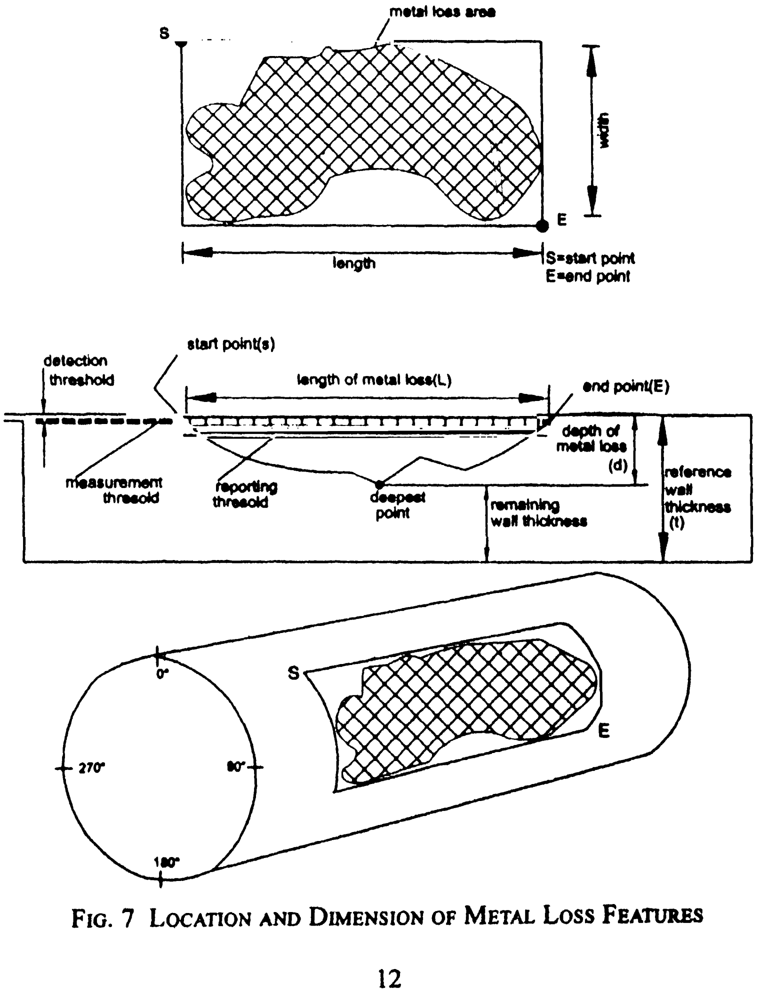


Fig. 7 Location and Dimension of Metal Loss Features

Table 1 Characterization Accuracy Levels for Various Types of Metal Loss Features
(*Clause* 10)

Sl No. (1)		Pinhole (2)	Axial Slotting (3)	Circular Slotting (4)	Pitting (5)	Axial Grooving (6)	Circular Grooving (7)	General (8)
A)	**LONGITUDINALLY WELDED PIPE (ERW): Full detection and sizing accuracy for metal loss features in pipe body**							
i)	Depth at POD 90 percent	Detectable	Detectable	10 percent w.t.	10 percent w.t.	±10 percent w.t.	10 percent w.t.	±10 percent w.t.
ii)	Depth sizing accuracy at 80 percent confidence	N/A	N/A	10 percent w.t.	10 percent w.t.	±10 percent w.t.	10 percent w.t.	±10 percent w.t.
iii)	Width sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.40"	±0.40"
iv)	Length sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.80"	±0.80"
B)	**SEAMLESS PIPE: Full detection and sizing accuracy for metal loss features in pipe body**							
i)	Depth at POD 90 percent	Detectable	Detectable	10 percent w.t.	10 percent w.t.	10 percent w.t.	10 percent w.t.	10 percent w.t.
ii)	Depth sizing accuracy at 80 percent confidence	N/A	N/A	15 percent w.t.	15 percent w.t.	±15 percent w.t.	15 percent w.t.	±15 percent w.t.
iii)	Width sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.40"	±0.40"
iv)	Length sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.80"	±0.80"
C)	**GIRTH WELD OR HEAT AFFECTED ZONE (HAZ): Full detection and sizing accuracy for metal loss features**							
i)	Depth at POD 90 percent	Detectable	Detectable	10 percent w.t.	10 percent w.t.	10 percent w.t.	10 percent w.t.	10 percent w.t.
ii)	Depth sizing accuracy at 80 percent confidence	N/A	N/A	20 percent w.t.	20 percent w.t.	±20 percent w.t.	20 percent w.t.	±20 percent w.t.
iii)	Width sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.40"	±0.40"
iv)	Length sizing accuracy at 80 percent confidence	0.40"	0.40"	0.40"	0.40"	±0.40"	0.80"	±0.80"

NOTES

1 The use of the term 'General' in this context does not correspond to the use of the term 'General corrosion' related to any governmental regulations or industry recommended practices.

2 Longitudinal location accuracy is ±4.0" from the nearest girth weld. Circumferential location accuracy is ±15 degrees or half an hour (clock orientations).

3 If $w.t. < 10$ mm, then $A = 10$ mm. Otherwise, $A = w.t.$ (wall thickness).

4 1" = 0254 mm.

recommended to carry out defect verification checks in the field by actual excavation at 2/3 flaw locations in the field.

11.1 Flaw Selection

While selecting the flaws for verification the following guidelines may be followed.

11.1.1 The larger anomalies with more than 20 percent wall thickness metal loss, which are likely to have greater impact on the pipeline integrity, may be preferred.

11.1.2 In case where defect verification activity is not possible (offshore pipeline, the defect lying under river/canal/water body crossing or the line segment does not have verifiable defects) the identification and characterization of pipeline permanent features such as valves, bands, tees etc. as reported by the inspection tool shall be considered for verification by comparing them with the pipe book.

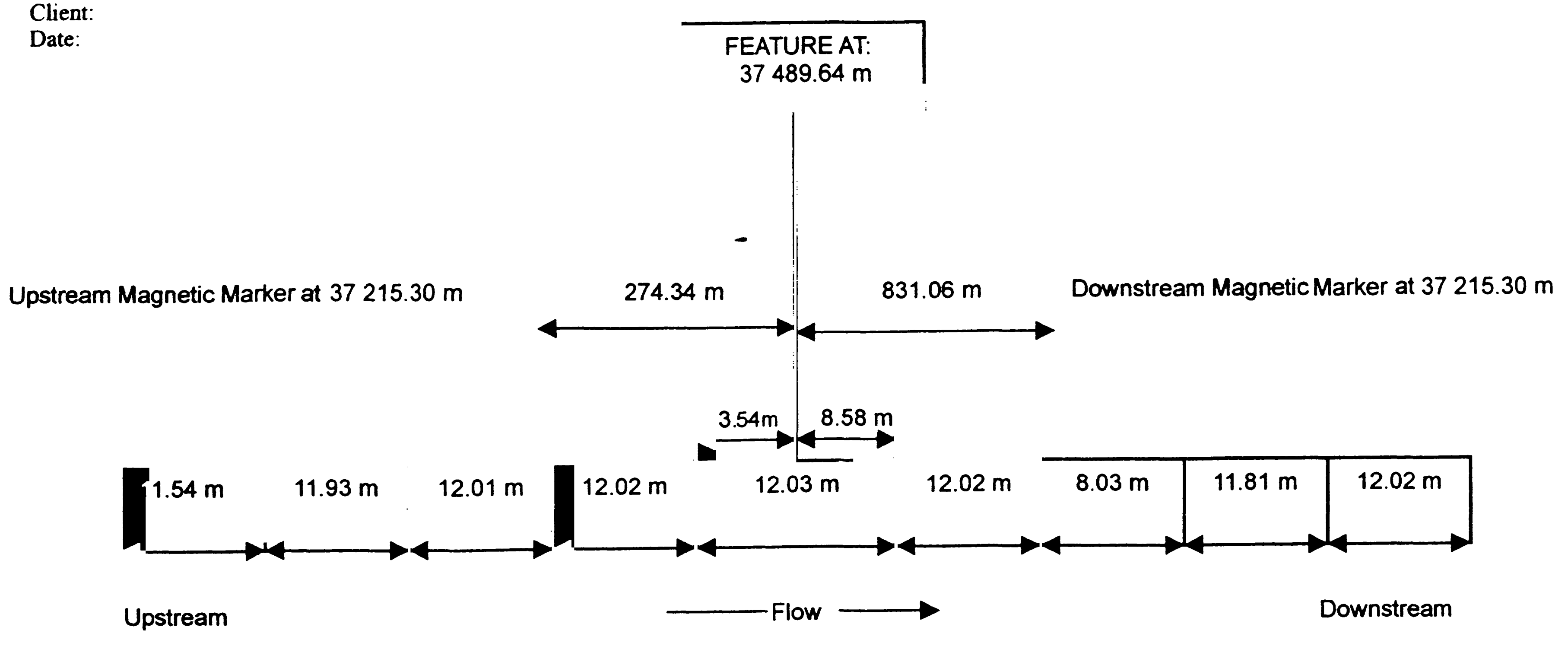
NOTE — Pipe book is a comprehensive document maintained by the organization engaged in this activity. It gives the details of each pipe length, bend, offtake tees, and other attachments including mainline valve, non-return valve to the main pipe line.

11.1.3 *Flaw Verification Procedure*

11.1.3.1 Select the flaws to be verified as per **11.1** from the report of the inspection agency.

11.1.3.2 A feature location sheet as per enclosed sample at Fig. 8 should be provided by the inspection

Dia 36" XYZ Pipeline
Client:
Date:



Type of flaw:	Metal loss		Description	General Corrosion	
Position:	00:30 o'clock		At internal pipe wall:	N.A.	Max. Depth of Metal loss: 20 percent
Length:	52 mm	width: 37 mm	Joint Wall thickness:	16.90 mm	
Comment:	The flaw is at External Surface				

FIG. 8 SAMPLE FLAW VERIFICATION SHEET

agency for each of the defects proposed to be verified.

11.1.3.3 Find the distance of the nearest above ground marker in the upstream and downstream directions

11.1.3.4 Both upstream and downstream closest references have to be used for taking over ground measurements to mark the location of the targeted flaw.

11.1.3.5 The two locations shall generally not match due to the fact that: (1) The above ground measurements consider the topography and does not necessarily include pipeline bend geometry or similar; and (2) Dirt or slippage could affect the wheel count based measurements.

11.1.3.6 Therefore, to minimize the discrepancies in the field, at least three pipe lengths on either side of the flaw should be excavated and girth weld to girth weld lengths as obtained in the field and those reported should match to confirm the exact spot.

11.1.3.7 Having obtained the flaw in the field, the measurements are taken as under:

a) Clean locally the pipe thoroughly, preferably by sand blasting;
b) Measure depth of anomaly at various locations and arrive at the deepest spot;
c) Measure length (longitudinally axis) and width (circumferential direction) of anomaly;
d) Sketch defect geometry including surrounding or take photo if possible;
e) Measure the average wall thickness in sound area close to the defect;
f) Mark on sketch/photo feature type (also anomalies like dents, gouges, mill defects etc. have to be described), log distance, orientation; and
g) Mark on Feature Location Sheet actual measured distance to girth weld, orientation, feature type, feature dimensions, actual wall thickness, etc.

11.1.3.8 Compare the data on flaw size, orientation and location with respect to the reported dimensions by applying suitable tolerances as per **10** to confirm the results.

12 TOOL SELECTION

In order to meet the objective as stated at **2**, it is essential to ensure the appropriateness of the tool selected for the inline inspection. The pipeline owner should match the relevant facts known about the pipeline and expected anomalies with the capability and performance of an inspection tool.

12.1 The following broad guidelines may be considered for tool selection:

a) *Standard/Conventional MFL Tools* — These tools can detect metal loss due to corrosion in a limited manner but cannot do defect sizing and internal/external wall discrimination. Further, these tools cannot detect any type of cracks and mid wall defects.
b) *High Resolution MFL Tools* — These tools can detect, identify and characterize metal loss due to corrosion or due to other reasons. These tools can discriminate between internal/external wall metal loss. These tools have higher accuracy levels and more reliable in data generation and can identify circumferential cracks.
c) *Transverse Field Inspection (TFI) Tools* — These tools can fulfil all the functions like a high-resolution tool and in addition can identify all types of longitudinal cracks but cannot identify circumferential cracks.

12.2 Tool Specifications

For the purposes of right tool selection for a specific pipeline, as a minimum the following data should be furnished by the tool owning agency to the pipeline owner.

12.2.1 Tool specification shall include:

a) Wall thickness range;
b) The magnetic field strength H in Am^{-1} as function of wall thickness (only for MFL pigs);
c) Speed range of the tool for valid data generation;
d) Temperature range;
e) Maximum pressure;
f) Minimum pressure for gas pipelines;
g) Minimum bend radius;
h) Minimum internal diameter;
j) Tool length, weight and number of segments;
k) Minimum length of pipeline that can be inspected in one run (may be coupled to run times and state of the pipeline);
m) Axial sampling frequency or distance;
n) Nominal circumferential sensor spacing/No. of sensors; and
p) Sizing and location accuracy of the features and flaws with respect to the upstream girth weld, the upstream marker and the orientation in the pipe.

12.2.2 If crack detection is possible and is included in the inspection scope of work, the contractor shall provide the following parameters:

a) Minimum depth and length for the detection of a crack,
b) The confidence level for the detection of this minimum crack,

c) The accuracy of sizing of crack length and depth,

d) The confidence level for the sizing performance,

e) The measurement of various pipeline features with applicable probability of identification, (POI) as per Table 2 shall be mentioned by tool owning agency as a part of tool specification/information, and

f) The sizing accuracy of various categories of defects shall be mentioned in Table 3 by tool owning agency.

13 TYPICAL INTELLIGENT PIGGING OPERATION

A typical intelligent pigging operation shall involve the activities such as pre-inspection activities, Field activities during intelligent pig run, post intelligent pig run activities including data analysis and reporting.

Typical pipeline preparation/inspection program have been presented in a tabular form as given at Annex A.

13.1 Pre-inspection Activities

The following preparatory activities need to be undertaken in the field for performing a successful intelligent pig run.

13.1.1 *Pull Through Test*

The proposed intelligent pigging tool shall be calibrated through a pull through test at tool owning agency's works before dispatch to site. The pull through test shall be performed on a set of test pipe pieces having a series of artificial defects. This test shall be performed preferably on such test pipes which have comparable wall thickness as the actual pipeline to be inspected and the tool velocity maintained during pull through test shall be nearly the same as expected during the actual run of the live tool in the field. Subsequent to the tool run in the test loop, the length, width and depth accuracy of known defects in the test loop shall be compared with the recorded data obtained out of the test run. Besides, the accuracy, relative weld distances, joint lengths and circumferential position of the defects shall also be checked with applicable tolerances. In case there is a mismatch the tool shall be recalibrated and tested again until this conformity is obtained. The magnetic field strength of the tool shall be measured and recorded during the test run.

13.1.2 *Information Review*

It is essential to make sure that known pipeline features such as valves will allow unhindered passage of the inspection tool. This calls for a thorough review of all available pipeline drawings and information. Further, the pipeline bends, elevations shall be known and it shall be established in advance that the inspection vehicle shall negotiate all the bends, curvatures and elevations of the pipeline. The presence of non-return/check valves in the pipeline shall be particularly checked and must be ensured that they are kept in lock open condition during the pig runs.

13.1.3 *Pipeline Cleaning and Geometry Assessment*

The quality of inspection data besides magnetization level and tool velocity largely depends on the contact between magnetic sensors and pipe wall. It is, therefore, essential that pipeline is reasonably cleaned by passing several cleaning pigs just before the instrumented pig survey is taken up. It is often advisable to make a few cleaning pig runs using special cleaning pigs such as

Table 2 Identification of Features
[*Clause* 12.2.2(e)]

Sl No. (1)	Feature (2)	Yes $POI > 90$ Percent (3)	No $POI < 50$ Percent (4)	May be $50 \le POI \le 90$ Percent (5)
i)	Internal/external discrimination			
ii)	Metal loss feature			
iii)	Metal loss pipe mill feature			
iv)	Mid-wall feature			
v)	Grinding			
vi)	Gouge			
vii)	Dent			
viii)	Dent with metal loss			
ix)	Spalling			
x)	Axial crack			
xi)	Circumferential crack			
xii)	Eccentric pipeline casing			
xiii)	Sleeve repair			
xiv)	Fitting			
xv)	Valve			
xvi)	Tee			
xvii)	Bends (5 *D* or less)			

Table 3 Full Identification and Sizing Accuracy for Metal Loss Features
[*Clause* 12.2.2(f)]

Sl No. (1)		Pinhole (2)	Axial Slotting (3)	Circular Slotting (4)	Pitting (5)	Axial Grooving (6)	Circular Grooving (7)	General (8)
A)	**In Body of Pipe**							
i)	Depth at POD 90 percent							
ii)	Depth sizing accuracy at 80 percent confidence							
iii)	Width sizing accuracy at 80 percent confidence							
iv)	Length sizing accuracy at 80 percent confidence							
B)	**In Girth Weld or Heat Affected Zone**							
i)	Depth at POD 90 percent							
ii)	Depth sizing accuracy at 80 percent confidence							
iii)	Width sizing accuracy at 80 percent confidence							
iv)	Length sizing accuracy at 80 percent confidence							

magnetic cleaning pigs besides brush cleaning to pick up metallic debris such as loose scale, leftover welding rods etc. to avoid possible damage of the live tool.

It is most advisable to run an electronic geometry pig (EGP) in the pipeline prior to live intelligent Pig run. This provides the information about the dents or any other possible pig movement/passage restrictions in the pipeline.

13.1.4 *Placement of Above Ground Markers*

Marking systems provide the reference locations, which establish a relationship between the locations of significant defects on the pipeline and those on the survey charts/logs. Reference sites shall be established prior to performing an inspection. The pipelines for which GPS (Geographical Positioning System) data (X, Y and Z co-ordinates with respect to a known reference) is available, need not be installed with any additional marker system during intelligent pigging. However, if GPS co-ordinates are to be utilized for defect location purposes, the live tool shall have an additional GPS pathfinder attachment. A pipeline marker will be placed at each location before the survey tool passes. The markers shall be placed maximum at an interval of 1-1.5 km. The following are two types of markers in vogue currently.

13.1.4.1 *Magnet marker system*

The system consists of a permanent magnet placed singly or in pairs over the pipeline and in its contact preferably at 12 O'clock position and detected by the MFL tool as it passes each of these locations. The signals caused by these permanent magnets are easily identified on the survey charts. The magnets shall be in contact with the pipe wall and pipe coating needs to be removed at magnet locations if coating thickness is more than 1.5 mm. However, in this regard the instructions must be obtained from the intelligent pig tool manufacturer. The use of permanent magnets is most efficient in areas where pipeline can be easily excavated and backfilled.

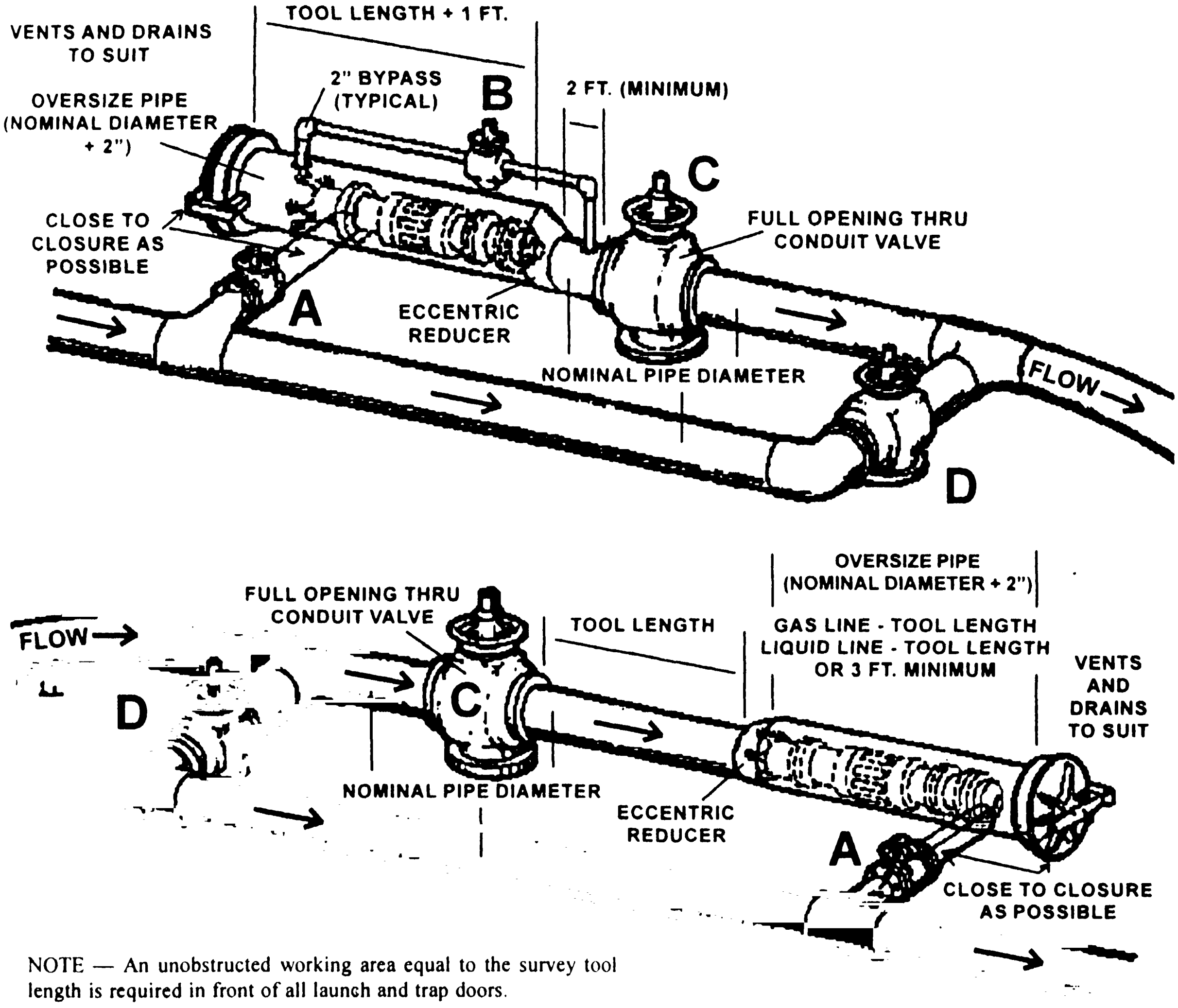
13.1.4.2 *Above ground marker coils*

Some of the intelligent pig tool manufacturers offer electro magnetic coils, which can be placed directly above the pipeline over ground. These coils transmit signals, which are picked up by the passing tool inside the pipeline. The location of these coils is marked permanently over ground so that the same can be tracked back at the time of defect verification. These coils have to be leap fogged during the live tool run.

13.2 Field Activities During Intelligent Pig Run

13.2.1 Having successfully completed the pipeline cleaning and Electronic geometry pigging the pre-calibrated live tool shall be launched into the pipeline. The generic launching procedure for a live tool is similar to launching a normal pipeline pig (*see* Fig. 9) and is briefly described as under.

13.2.2 During insertion, valves *A* and *C* will be closed while valves *B* and *D* will be open. When the launch closure is sealed, pressure up the barrel slowly by


VENTS AND DRAINS TO SUIT
TOOL LENGTH + 1 FT.
2" BYPASS (TYPICAL)
B
2 FT. (MINIMUM)
OVERSIZE PIPE (NOMINAL DIAMETER + 2")
C
CLOSE TO CLOSURE AS POSSIBLE
FULL OPENING THRU CONDUIT VALVE
A
ECCENTRIC REDUCER
NOMINAL PIPE DIAMETER
FLOW
D
OVERSIZE PIPE (NOMINAL DIAMETER + 2")
FULL OPENING THRU CONDUIT VALVE
TOOL LENGTH
GAS LINE - TOOL LENGTH
LIQUID LINE - TOOL LENGTH OR 3 FT. MINIMUM
FLOW
D
C
VENTS AND DRAINS TO SUIT
NOMINAL PIPE DIAMETER
ECCENTRIC REDUCER
A
CLOSE TO CLOSURE AS POSSIBLE

NOTE — An unobstructed working area equal to the survey tool length is required in front of all launch and trap doors.

FIG. 9 TYPICAL LAUNCHER/RECEIVER ARRANGEMENT

"cracking" valve *A*. Bringing up the pressure slowly prevents damage to the tool and lessens the chance of running the tool into the launcher valve *C*. With the barrel equalized to line pressure, open valve *C* making certain it is fully open. Next, open valve *A* fully and close valve *B*. Slowly and steadily start closing valve *D*. These will divert the flow through valve *A* into the barrel behind the tool. When the tool launches and is past the 'tee', open valve *D* fully. Restore the launch trap to its normal condition.

13.2.3 Natural gas is a compressible medium. This makes tool behavior very unpredictable when receiving. Generic guidelines are not possible since exact trap configuration, line pressure, and throughput vary greatly from one pipeline to another. Procedures must be based on the pipeline operator's experience with a particular receiver trap. Due consideration must be given to the extra length and weight of a live tool and existing procedures must be modified accordingly.

13.2.4 *Removing the Tool*

Blow down the barrel slowly. If possible, verify that the pressure has been relieved on both sides of the tool. Open the end closure and block up the handling tray so that it is even and level with the barrel. Secure the tray to the barrel so that it cannot move out of position when the tool is pulled out. Using the tool's nosepiece as a pull cable attachment point, gently ease the tool out of the barrel and onto the handling tray. Inspect the tool closely for line induced damage and excess debris.

The tool shall be tracked at every 5-10 km interval to ensure its smooth movement into the pipeline until it is received in the receiving trap.

13.3 Post Intelligent Pig Run Activities Including Data Assessment

During the intelligent pig tool run the data is recorded in the solid-state memory of the computer and can be viewed in a digitized format on a computer. Each signal channel displays indications recorded by an individual sensor on the survey tool. Channel traces remain relatively flat until a recorded deviation in pipe wall or other event causes a flux leakage signal proportional to the magnitude of the event. These events appear on the log as sine waves of varying amplitudes and frequencies. Depending on their geometry, polarity, grouping, orientation, and other characteristics, signals are recognizable as either loss of pipe wall or as valves, tees, taps, casings, sleeves, and other pipeline features. Additional data channels provide other important survey information. The magnet marker channels display magnet positions and aid in identifying welds, casings, dents, and bends. A time channel indicates the positions of Linacron above ground reference markers placed during the run. A binary code channel displays distance, orientation, and tool speed data. Following the recording of data, tool performance within the specified tolerance shall be verified. This has to be done in conformity with the details given at **10**.

13.4 Reporting

The typical final inspection report shall contain the following information:

a) Tool operational data,
b) Pipe tally,
c) List of features,
d) Summary and statistical data,
e) Fully assessed feature sheets, and
f) Defect assessment method.

13.4.1 *Tool Operational Data*

The tool specifications shall be given. In addition the following operational data shall be provided:

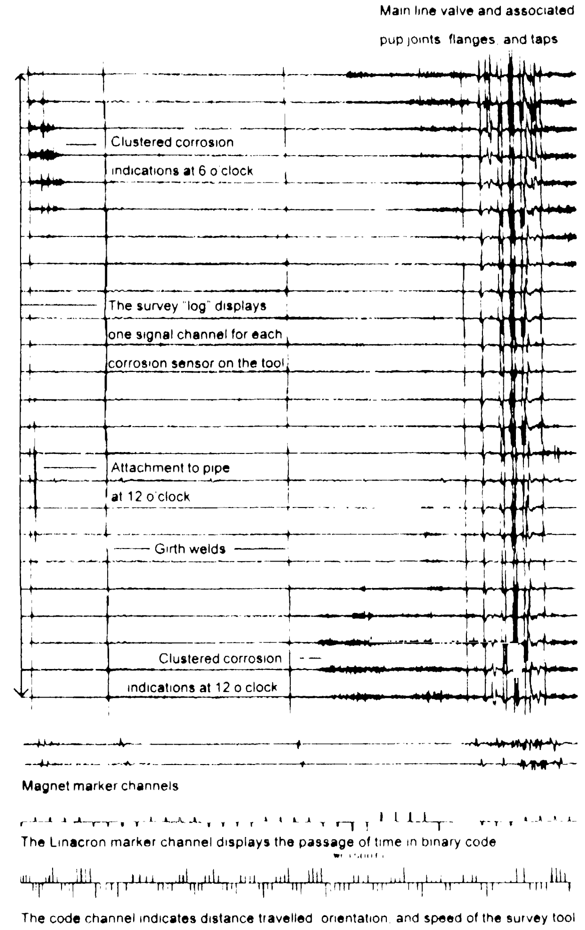
a) Data-sampling frequency or distance;
b) Detection threshold;
c) Reporting threshold, normally taken at 90 percent POD, if not specified otherwise;
d) A tool velocity plot over the length of the pipeline (*see* Fig. 10);
e) Optionally, a pressure and/or temperature plot over the length of the pipeline; and
f) In case of MFL pigs, the magnetic field strength H in Am^{-1}.

The tool operational data shall indicate whether the tool has functioned according to specification, it shall detail all locations where the measurement specifications are not met.

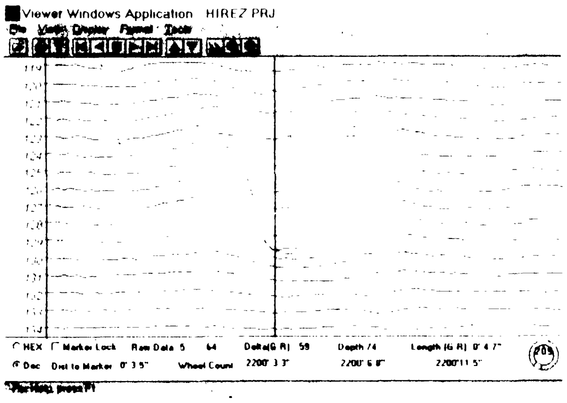
13.4.2 *Pipe Tally*

The pipe tally shall contain numbering of all pipe joints and listing of all girth welds by log distance, listing of each joint length and listing of all pipeline installations including fittings, valves, tees, markers, CP points, etc.

13.4.2.1 The joint numbering shall start at the first joint after the first line valve. The zero position of the log distance shall be the center-point of the first line valve.



Printed survey records are a standard format for analog conventional resolution surveys. Linalog Plus surveys may be presented in printed or digitized formats.



Digitized data presented via a computer monitor is the standard format for high resolution TruRes surveys.

FIG. 10 TYPICAL DATA CHARTS

13.4.2.2 The pipe tally list shall contain the parameters:

a) Log distance, in m;
b) Joint number giving log distance at upstream girth weld;
c) Joint length, in m; and
d) Description of installation.

13.4.3 *List of Features*

All features with dimensions above the reporting threshold at 90 percent POD or above a reporting threshold as subscribed in the technical scope of work of the contract shall be reported in the list of features.

The list of features shall contain the following parameters:

a) Log distance;
b) Joint number;
c) Nominal pipe wall thickness or reference wall thickness as measured by the tool;
d) Feature description adjacent to girth weld;
e) Distance to upstream girth weld;
f) Orientation;
g) Feature length, width and depth;
h) ERF (Estimated Repair Factor); and
j) Internal/external/mid-wall indication.

The accuracy levels of measurement in the above fields shall be in conformity with **9**.

13.4.4 *Summary and Statistical Data*

The summary data shall contain the following information:

a) Total number of metal loss features,
b) Number of internal metal loss features,
c) Number of external metal loss features,
d) Number of general metal loss features,
e) Number of pits,
f) Number of axial and circumferential grooves,
g) Number of metal loss features with depth 0-9 percent,
h) Number of metal loss features with depth 10-19 percent,
j) Number of metal loss features with depth 20-29 percent,
k) Number of metal loss features with depth 30-39 percent,
m) Number of metal loss features with depth 40-49 percent,
n) Number of metal loss features with depth 50-59 percent,
p) Number of metal loss features with depth 60-69 percent,
q) Number of metal loss features with depth 70-79 percent,
r) Number of metal loss features with depth 80-89 percent,
s) Number of metal loss features with depth 90-100 percent,
t) Number of metal loss features with $0.6 \leq$ ERF ≤ 0.8,
u) Number of metal loss features with $0.8 \leq$ ERF ≤ 0.9,
v) Number of metal loss features with $0.9 \leq$ ERF ≤ 1.0, and
w) Number of metal-loss features with ERF ≥ 1.0.

13.4.5 The following histograms shall be provided over the entire pipeline length:

a) Number of metal loss features in 500 m sections,
b) Number of metal loss features in 500 m sections with depth $\geq 0.4\ t$,
c) Number of metal loss features in 500 m sections with depth $\geq 0.6\ t$,
d) Number of metal loss features in 500 m sections with ERF ≥ 0.8, and
e) Number of metal loss features in 500 m sections with ERF ≥ 1.0.

NOTE — ERF is Estimated Repair Factor.

13.4.6 The following plots (graphical presentations) shall be provided:

a) Sentenced plot including ERF = 1 curve of metal loss feature length against metal loss feature depth showing all metal loss features for the predominant wall thickness,
b) Orientation plot of all metal loss features over the full pipeline length,
c) Orientation plot of all internal metal loss features over the full pipeline length,
d) Orientation plot of all external metal loss features over the full pipeline length, and
e) Orientation plot of all metal loss features as function of relative distance to the closest girth weld.

13.4.7 *Fully Assessed Feature Sheets (Dig Up Sheets)*

Fully assessed feature sheets shall be provided as a minimum for the 10 most serious metal loss indications. Selection of the most serious metal loss indications can be based on depth or as defined in technical scope of work in the contract.

Fully assessed feature sheets shall contain the following information to the full sizing specification:

a) Length of pipe joint and orientation of longitudinal seam (when present),
b) Length and longitudinal seam orientation of the 3 upstream and 3 downstream neighbouring pipe joints,
c) Distance of upstream girth weld to nearest upstream marker,
d) Distance of upstream girth weld to nearest downstream marker,
e) Distance of metal loss feature to upstream girth weld,
f) Distance of metal loss feature to downstream girth weld,
g) Orientation of metal loss feature,
h) Feature description and dimensions, and
j) Internal/external/mid-wall indication.

14 SAFETY PRECAUTION DURING PIGGING OPERATION

Safety is of paramount importance during pigging, as pigs are used in pipelines carrying hazardous gases, pyrophoric gases, and asphyxiants and operating under high pressure.

Safety in pigging operations is concerned with several areas, including access to pressure vessels, exposure to hazardous gases, and the mechanical aspects of launching and receiving pigs.

Safe operation is achieved by a combination of good management systems, proper equipment maintenance and mechanical handling of pigs by experienced work crews, and basic safety procedures.

Accidents appear to fall into three main areas of handling pressurized equipment, loading and unloading of pigs and defective equipment such as pressure gauges.

Besides, common safety precautions the following specific safety measures need to be taken during pigging operations.

14.1 Pyrophoric Materials

Pyrophoric materials particularly iron sulphide can be produced from a pipeline by efficient cleaning action of either cleaning tools or live inspection tools. Additional vigilance is required to ensure that fires are not initiated. For this purpose a fire tender should be kept ready at the receiver terminal and immediately after opening the receiver barrel gate, the material that comes out of the barrel should be drenched with water. Besides, thorough wetting, provisions should be made for the collection, removal and safe disposal of suspected pyrophoric and other materials coming out of the pipeline receiver barrel.

14.2 Hydrate Precautions

When a line has the potential to form hydrates, provisions should be made for their collection, removal and safe disposal.

14.3 Slug Collection

In case of two-phase flow gas lines intelligent pig tools and other cleaning/geometry pigs shall produce abnormal amount of slug/process fluids. The quantity of process slug shall be assessed in advance and provisions must be made for collection of this additional slug volume. Temporary tankage/piping connection may be required to divert and collection of this additional slug volume.

14.4 It is recommended that written safety procedures shall be established before the commencement of a pigging programme. Pre-job safety meetings are recommended with all concerned personnel including the operators, contractors and supervisory personnel. A typical written procedure is given as Annex B.

14.5 Environmental Protection

14.5.1 Minimization of gas venting by appropriate planning.

14.5.2 Minimization of spillage/land contamination by provision of appropriate collection facility.

14.5.3 Appropriate disposal of solid and liquid waste to authorized land filled site.

15 BASE LINE SURVEY

15.1 Base line surveys are conducted prior to or very shortly after the start of normal service of the pipeline. It is recommended that immediately after completion of construction activities at site an electronic geometry pigging survey should be conducted as a part of pre-service works. This can be done by propelling the required pigs by the usage of compressed air. A pre-service electronic geometry pigging survey offers the benefit of confirmation that the contractors during construction have delivered all the system as required by the contract. Moreover, any abnormal geometrical deformity observed, which might have resulted due to inadvertant backfilling or other construction activities shall be known before the pipeline is put into service. These pipe lengths can be cut and removed while the pipe-laying contractor is still at site. If repairs are made to a pipeline during construction following the base line surveys, the locations of these repairs should be recorded and incorporated into the permanent pipeline records.

15.2 The advantage of performing a base line survey is to provide a figure print of the pipe steel in its 'as laid' condition. Subsequent inspections can then identify and evaluate the real problems in the form of corrosion, from spurious indications (mill induced or constructional faults). Once this is achieved, the frequency of further inspection and a policy for corrosion monitoring can then be established. To enable this philosophy to work, a level of confidence in the inspection system employed must be obtained by the operator of the pipeline. Once this level of confidence has been achieved, considerable cost savings can be made by eliminating the amount of excavations. Following a base line survey and a further inspection within 3 to 5 years, the deterioration (if any) of the pipeline condition can be assessed and provide a basis for any remedial action on the pipeline protection system (s). The success of which can be monitored by future inspection runs, using the same equipment.

15.3 It is useful to conduct an inline inspection survey of the pipeline very shortly (preferably within one year) after the start of service. This will provide the base line data for future inline inspection surveys. The data obtained during base line shall be very useful while evaluating the data obtained during future surveys. The comparison shall help in taking optimum decisions about the repairs/replacements and making a Residual Life Assessment of the pipeline.

16 CONTINGENCY PLAN

16.1 Notwithstanding, the best of preparation and planning, the occurrence of contingency situations cannot be completely ruled out. Therefore it is recommended that provision shall be made for at least the following type of contingencies while a pipeline pigging programme is undertaken.

16.2 Contingency Arising Out of Stuck Pig

16.2.1 Any pig (except the foam pig which are highly flexible and generally get shredded, if stuck and therefore can come out into pieces) has a potential to get lodged into the pipeline due to various reasons. This includes hindrances caused by mainline valves, non-return (check) valves, pipeline deformity, mechanical breakdown of the pig, sudden stoppage of pipeline flow, abnormal tee or spur connection, etc.

16.2.2 Each pig stuck scenario is unique and a careful analysis should be done before taking any steps to dislodge the stuck pig. It is therefore not possible to formulate any general procedure for releasing the stuck pig. However, certain generic guidelines are as under.

16.2.2.1 As soon as it is confirmed that the pig has got stuck, immediate steps should be taken to find the exact location of the stuck pig in the pipeline. It is therefore essential to ensure that each pig (except the foam) that is introduced into the pipeline is equipped with a pig-locating device having sufficient battery life (at least 72 h) to provide adequate time for pig location in the field.

16.2.2.2 In case these efforts fail, and if circumstantially it is confirmed that the pig has mechanically broken down (in such cases full pipeline flow shall continue despite non-movement of pig) it is preferable to launch another soft pig [foam or 'bi-directional (Bi-Di)]' to push out the broken components of the lodged pig. However, if all the above efforts fail to remove the lodged pig, cutting the pipeline through hot tapping remains the only option to restore the normalcy. An investigative analysis immediately after the pig recovery should be done by experts and reasons should be recorded to avoid such situations in future.

16.3 Contingency Due to Sudden Stoppage of Flow

This can happen due to total power failure or any major mechanical or electrical breakdown in the compressor/pumping system and can lead to stoppage of the pig. Generally the pig movement shall restart unless the pig get stuck at some abnormal location during flow stoppage.

16.4 Sudden Failure of Pipeline

In case sudden burst/major leak/third party activity damage occurs when the pig is inside the pipeline, a situation similar to **16.2** shall occur.

16.5 Contingency arising due to excess amount of condensate/water mixtures and/or black dust/iron oxide coming out along with cleaning pig or Intelligent tool shall be taken care. The following shall be considered for contingency:

a) Adequate amount of condensate/dust collection facility,

b) Appropriate design and installation of collection facility,

c) Operation procedure for collection of condensate/dust,

d) Control/reduction of speed for last few kilometers of travel,

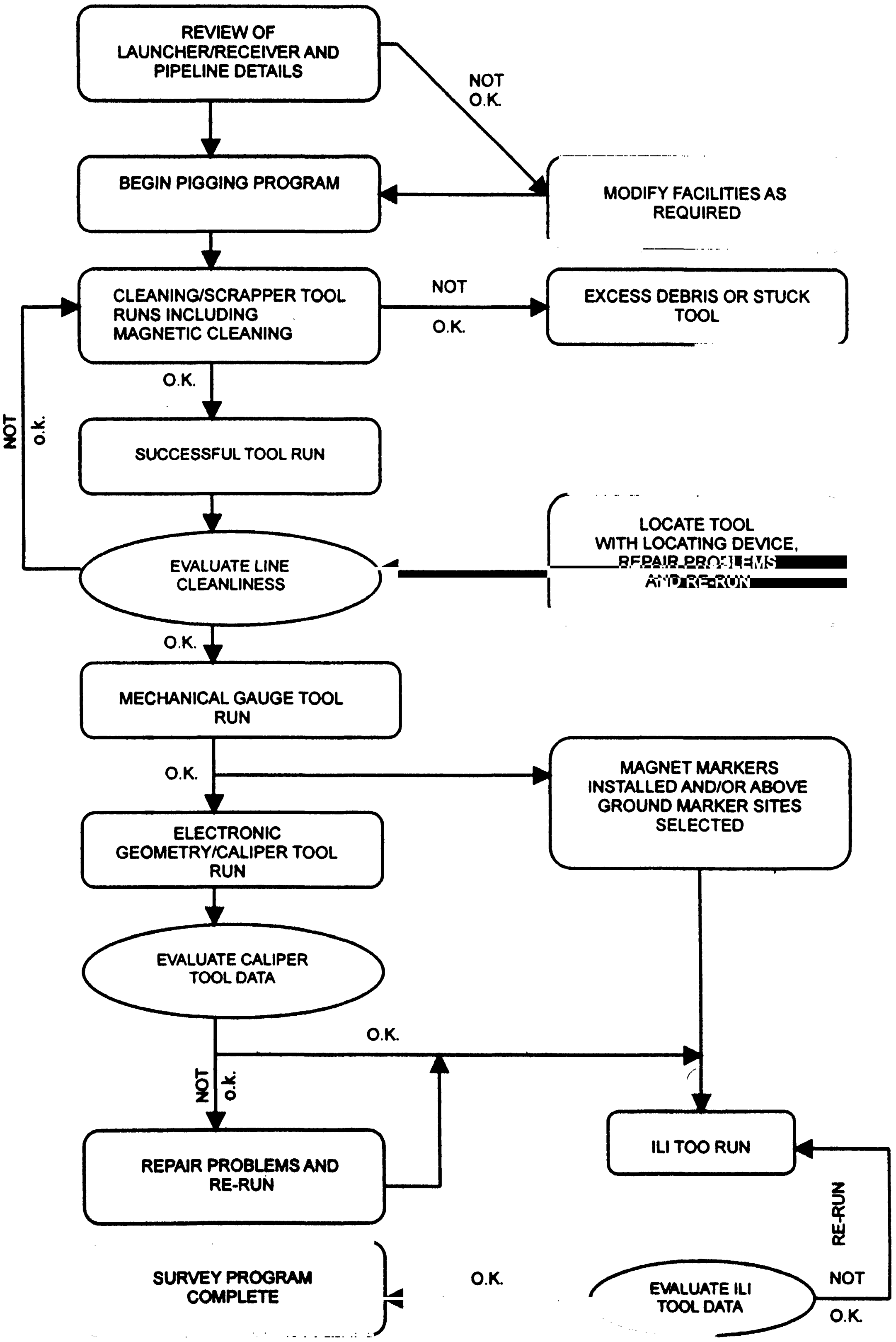
e) Readiness of fire fighting, and

f) Communication and readiness for curtailment/stoppage of gas supply to downstream customers.

ANNEX A

(*Clause* 13)

TYPICAL LINE PREPARATION/INSPECTION PROGRAMME


REVIEW OF LAUNCHER/RECEIVER AND PIPELINE DETAILS
NOT O.K.
BEGIN PIGGING PROGRAM
MODIFY FACILITIES AS REQUIRED
CLEANING/SCRAPPER TOOL RUNS INCLUDING MAGNETIC CLEANING
NOT O.K.
EXCESS DEBRIS OR STUCK TOOL
O.K.
NOT o.k.
SUCCESSFUL TOOL RUN
LOCATE TOOL WITH LOCATING DEVICE, REPAIR PROBLEMS AND RE-RUN
EVALUATE LINE CLEANLINESS
O.K.
MECHANICAL GAUGE TOOL RUN
O.K.
MAGNET MARKERS INSTALLED AND/OR ABOVE GROUND MARKER SITES SELECTED
ELECTRONIC GEOMETRY/CALIPER TOOL RUN
EVALUATE CALIPER TOOL DATA
O.K.
NOT o.k.
REPAIR PROBLEMS AND RE-RUN
ILI TOO RUN
RE-RUN
SURVEY PROGRAM COMPLETE
O.K.
EVALUATE ILI TOOL DATA
NOT
O.K.

ANNEX B

(*Clause* 14.4)

SAMPLE WRITTEN PROCEDURE: SAFETY IN PIPELINE PIGGING

B-1 If not directly involved with the operation of the pig traps, stay away from the area.

B-2 Generally a two man teams should perform most of the jobs.

B-3 Pressure test main line ball valves on pipelines that are not frequently pigged.

B-4 Hold pressure build-up rate to a minimum during launching procedures. Do not exceed the MAOP (Maximum Allowable Operating Pressure) of the facilities.

B-5 Eliminate sources of ignition, particularly in the launcher and receiver areas.

B-6 Keep fire extinguishers/fire tender readily available on site of receiver/launcher.

B-7 If there is a history of iron sulphide being present, have a supply of water or other fire or heat suppressing materials available when opening the barrel.

B-8 Ensure ball valves, used as launcher or receiver valves, have body bleeds blown down before barrel door is open.

B-9 Do not open the closure until the trap has been blown down.

B-10 Do not blow back lodged pigs (spheres, squeegees) through an open launcher or blow forward through an open receiver at full line pressure. Treat a lodged pig similar to a solid line freeze and clear accordingly.

B-11 Do not stand in the projected path of the end closure while opening.

B-12 Wear protective clothing and equipment when removing a pig from the trap.

This includes full breathing apparatus when hydrogen sulphide or nitrogen is in use.

B-13 Ensure the provision and use of dust mask while opening of receiver and removal of pig and dust from barrel.

B-14 Ensure the provision of hydrocarbon detector at pig receipt site and monitoring of hydrocarbon (methane) in downstream wind direction in case of gas venting.

(Continued from second cover)

ASME B 31G : 1991	Manual for determining the remaining strength of corroded pipelines (Supplement to B31 Code – Pressure piping) Specification and requirement for intelligent pig inspection of pipelines, version 2.1, 9 November 98 – Pipeline Operator's Forum (POF) Document

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc: No. **PCD 3 (2349).**

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *website* : www.bis.org.in

Regional Offices: Telephones

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002 {2323 7617, 2323 3841}

Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054 {2337 8499, 2337 8561, 2337 8626, 2337 9120}

Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022 {260 3843, 260 9285}

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113 {2254 1216, 2254 1442, 2254 2519, 2254 2315}

Western : Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400093 {2832 9295, 2832 7858, 2832 7891, 2832 7892}

Branches : AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. NALAGARH. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

Printed at Simco Printing Press, Delhi